PORTLAND HARBOR RI/FS

FINAL REMEDIAL INVESTIGATION REPORT

APPENDIX G
BASELINE ECOLOGICAL RISK ASSESSMENT

FINAL

Volume I

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Prepared for
The Lower Willamette Group and
United States Environmental Protection Agency

Prepared by
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LIST OF ACRONYMS

Acronym	Definition
2,4-D	2,4-dichlorophenoxyacetic acid
2,4-DB	4-(2,4-dichlorophenoxy)butyric acid
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
ACR	acute-to-chronic ratio
AET	apparent effects threshold
Ah	aryl hydrocarbon
ANOVA	analysis of variance
AOC	area of concern
AOPC	area of potential concern
aRPD	apparent redox potential discontinuity
ASL	aqueous solubility limits
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
AVS	acid volatile sulfide
AWQC	ambient water quality criteria
BAF	bioaccumulation factor
BCF	bioconcentration factor
BDL	below detection limit
BEHP	bis(2-ethylhexyl) phthalate
BERA	baseline ecological risk assessment
BEST	Biomonitoring of Environmental Status and Trends (protocol)
BHHRA	baseline human health risk assessment
BLM	biotic ligand model
BSAF	biota-sediment accumulation factor
BSAR	biota-sediment accumulation regression
bw or BW	body weight
°C	degrees Celsius
C10-C25	diesel-range hydrocarbons
C25-C36	residual-range hydrocarbons
C6-C10	gasoline-range hydrocarbons

Acronym	Definition
$CaCO_3$	calcium carbonate
CBFWA	Columbia Basin Fish and Wildlife Authority
CBR	critical body residue
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFD	cumulative frequency distribution
cfs	cubic feet per second
cm	centimeter
COC	contaminant of (ecological) concern
COI	contaminant of interest
COPC	contaminant of potential concern
CRD	Columbia River Datum
CSL	cleanup screening level
CSM	conceptual site model
D	detected
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DDx	sum of all six DDT isomers (2,4′-DDD; 4,4′-DDD; 2,4′-DDE; 4,4′-DDE; 2,4′-DDT; and 4,4′-DDT)
DL	detection limit
DNA	deoxyribonucleic acid
DQO	data quality objective
dw	dry weight
EC50	concentration that causes a non-lethal effect in 50% of an exposed population
Eco-SSL	ecological soil screening level
ECOTOX	EPA's ecotoxicology database
EE/CA	engineering evaluation/cost analysis
EF	exceedance factor
EPA	US Environmental Protection Agency
EPC	exposure point concentration

Acronym	Definition
ERA	ecological risk assessment
ERAGS	Ecological Risk Assessment Guidance for Superfund
ERED	Environmental Residue Effects Database
ERL	effects range – low
ERM	effects range – median
EROD	ethoxyresorufin-O-deethylase
ESA	Endangered Species Act
ESB	equilibrium partitioning sediment benchmark
FACU	facultative upland; low to moderate probability of occurrence in regional wetlands
FACW	facultative wet; moderate to high probability of occurrence in regional wetlands
FAV	final acute value
FCV	final chronic value
FIR	food ingestion rate
FN	false negative
FP	false positive
FPM	floating percentile model
FRV	final residue value
FS	feasibility study
FSP	field sampling plan
ft	foot
FWM	food web model
g	gram
GIS	geographic information system
GMAV	genus mean acute value
GWPA	groundwater pathway assessment
HCH	hexachlorocyclohexane
HHRA	human health risk assessment
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
HQ	hazard quotient
IC20	concentration required for 20% inhibition of an effect

Acronym	Definition
ID	identification
in.	inch
IR	ingestion rate
IRIS	Integrated Risk Information System
ISA	initial study area
IWC	integrated water column
J-qualifier	estimated concentration
JSCS	Joint Source Control Strategy
kg	kilogram
km	kilometer
km^2	square kilometer
K_{OW}	octanol-water partition coefficient
L	liter
L0	Level 0 (non-toxic)
L1	Level 1 (low toxicity)
L2	Level 2 (moderate toxicity)
L3	Level 3 (high toxicity)
LC50	concentration that is lethal to 50% of an exposed population
LC10	concentration that is lethal to 10% of an exposed population
LC100	absolute lethal concentration – lowest concentration of a substance in an environmental medium that kills 100% of test organisms or species under defined conditions
LCV	lowest chronic value
LD50	dose that is lethal to 50% of an exposed population
LOAEL	lowest-observed-adverse-effect level
LOE	line of evidence
LOEC	lowest-observed-effect concentration
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon
LRM	logistic regression model
LWG	Lower Willamette Group
LWR	Lower Willamette River
m	meter

Acronym	Definition
m^2	square meter
MATC	maximum acceptable toxicant concentration
MCPA	2-methyl-4-chlorophenoxyacetic acid
MCPP	methylchlorophenoxypropionic acid
mg	milligram
mi	mile
mL	milliliter
mm	millimeter
MQ	mean quotient
MSD	minimum significant difference
n or N	number of samples
N-qualifier	presumptive evidence of a compound
NA	not available
NAPL	non-aqueous-phase liquid
NAVD	North American Vertical Datum
NE	not evaluated
ng	nanograms
NMFS	National Marine Fisheries Service
NN	natural neighbors
No.	number
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no-observed-adverse-effect level
NOEC	no-observed-effect concentration
NRC	National Research Council
O&M	operation and maintenance
OBL	obligate; high probability of occurrence in regional wetlands
OC	organic carbon
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
OHWM	ordinary high water mark
OSWER	Office of Solid Waste and Emergency Response
p	probability

Acronym	Definition
PABAK	prevalence- and bias-adjusted (Cohen's) kappa
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEC	probable effects concentration
PEC-Q_{dw}	mean PEC quotient
PEL	probable effects level
pg	picogram
PIT	passive integrated transponder
pMax	maximum probability of toxicity
PRE	preliminary risk evaluation
PRG	preliminary remediation goal
QC	quality assurance
QAPP	quality assurance project plan
QC	quality control
r^2	coefficient of determination
REV	reference envelope value
RI	remedial investigation
RM	river mile
ROC	receptor of concern
RSET	Regional Sediment Evaluation Team
SAP	sampling and analysis plan
SCRA	site characterization and risk assessment
sd	standard deviation
SEM	simultaneously extracted metals
SIR	sediment ingestion rate
SL	screening level
SL1	screening level 1
SLERA	screening-level ecological risk assessment
SMAV	species mean acute value
SMDP	scientific/management decision point
SOW	scope of work
SP&S	Spokane, Portland, and Seattle

Acronym	Definition
SPI	sediment profile imaging
SQG	sediment quality guideline
SQS	sediment quality standards
SQV	sediment quality value
SSD	species sensitivity distribution
SUF	site use factor
SVOC	semivolatile organic compound
SW	surface water
SWAC	spatially weighted average concentration
SWI	sediment-water interface
T-qualifier	value calculated or selected from multiple results
TBT	tributyltin
T/C	mean treatment response divided by mean control response
TCDD	tetrachlorodibenzo-*p*-dioxin
TEC	threshold effects concentration
TEF	toxic equivalency factor
TEL	threshold effects level
TEQ	toxic equivalent
TFM	3-trifluormethyl-4-nitrophenol
TOC	total organic carbon
TP	true positive
TPH	total petroleum hydrocarbons
TREAD	Tissue Residue Effects Association Database
TRV	toxicity reference value
TSC	threshold sediment concentration
TTC	threshold tissue concentration
TU	toxicity unit
TZW	transition zone water
UCL	upper confidence limit on the mean
UF	uncertainty factor
UPL	upper prediction limit
USACE	US Army Corps of Engineers

Acronym	Definition
USC	United States Code
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey
UV	ultraviolet
VOC	volatile organic compound
WDFW	Washington State Department of Fish and Wildlife
WDG	Washington Department of Game
WHO	World Health Organization
WOE	weight of evidence
WQS	water quality standards
ww	wet weight
XAD	Infiltrex™ 300 system with an XAD-2 resin column
µg	microgram
µ	micrometer

GLOSSARY

Term	Definition
acute	occurring within a short period of time, typically an hour to a day in ecotoxicology
acute-to-chronic ratio	the ratio of the concentration at which acute effects occur to that at which chronic effects occur
aliphatic hydrocarbons	hydrocarbon compounds that contain carbon and hydrogen joined together in straight chains, branched chains, or non-aromatic rings
ambient water quality criterion	contaminant concentration considered to be protective of aquatic biota
ammocoete	filter-feeding larval life stage of the lamprey
anadromous	describes fish species that migrate to saltwater and then return to freshwater rivers and lakes to breed
apparent redox potential discontinuity depth	an estimation of the depth at which the oxygenated surface sediment layer transitions to anoxic conditions; used as a measure of community succession in the sediment profile imaging analysis
aromatic hydrocarbons	hydrocarbon compounds that contain a benzene ring
assessment endpoint	the explicit expression of an environmental value to be protected
baseline ecological risk assessment	a process that evaluates the likelihood that adverse ecological effects are occurring as a result of exposure to one or more stressors, uncertainties associated with the evaluation, and the ecological significance of the adverse effects. The process provides information useful in determining whether a current threat to the environment exists that warrants remedial action.
benthic	relating to or characteristic of the bottom of an aquatic body or the organisms and plants that live there
benthopelagic	living and feeding (on benthic as well as free-swimming organisms) on the bottom as well as throughout the water column
benthos	organisms that live in or on the sediment or other bottom substrates in a water body
bioaccumulation	the accumulation of a substance in an organism
bioconcentration factor	the concentration of a contaminant in the tissues of an organism divided by the concentration in water
biomagnification	the increase in concentration of a substance in the tissue of an organism within each successive increase of trophic level

Term	Definition
biomagnification regression	a mathematical equation that attempts to describe the relationship between the concentration of a chemical in prey tissue and the concentration of the chemical in predator/consumer tissue using co-located data pairs
biota-sediment accumulation factor	the ratio of the concentration of a contaminant in the tissue of an organism to the concentration in sediment
biota-sediment accumulation regression	a mathematical equation that attempts to describe the relationship between the concentration of a contaminant in the tissue of an organism and the concentration of the contaminant in sediment using co-located data pairs
bioturbation	the disturbance of sediment by the actions of organisms living on or in the bottom
Category 1/QA2	Category 1 data are of known quality and are considered to be acceptable for use in decision making for the Portland Harbor Site. There is sufficient information on these datasets to confidently verify that the data, along with associated data qualifiers, accurately represent chemical concentrations present at the time of sampling. Only Category 1 data that have had an EPA-approved level of data validation, comparable to Washington State Department of Ecology's "QA2" evaluation, were used for human health or ecological risk assessments (Integral et al. 2004b).
cleanup action	This is the outcome of a remedial action decision. A cleanup action may involve no further action, institutional controls, monitored natural recovery, or a range of active remedial alternatives including in-place and removal actions.
coefficient of determination	This indicates how well data points fit a line or curve. The coefficient of determination ranges from 0 to 1. Values closer to 1 show greater fit.
contaminant of (ecological) concern (COC)	a substance detected at a National Priorities List site that has the potential to affect ecological receptors adversely due to its concentration, distribution, and mode of toxicity (the modifier 'ecological' is assumed, not explicitly stated in the BERA). Synonymous with contaminant posing potentially unacceptable risk.

Term	Definition
contaminant of ecological significance (ecologically significant contaminant)	a subset of contaminants posing potentially unacceptable risk at the end of the BERA that, based on professional judgment of site ecological risk assessors, are necessary and sufficient to develop and evaluate remedial alternatives protective of the environmental values and ecological resources described by the assessment endpoints of the baseline ecological risk assessment
contaminant of interest (COI)	contaminant detected in the Study Area through RI/FS data gathering in any exposure medium (i.e., surface water, transition zone water, sediment, and tissue)
contaminant of potential concern (COPC)	the subset of contaminants of interest with maximum detected concentrations that are greater than screening-level effect thresholds
contaminant posing potentially unacceptable risk	the subset of contaminants of potential concern exceeding toxicity reference values in the final step of the risk characterization plus the detected contaminants of potential concern whose risks cannot be quantified with baseline toxicity reference values. Synonymous with contaminant of (ecological) concern.
chironomid	small non-biting midges (in the fly family) with an aquatic larval stage during which they significantly contribute to the benthic biomass of an ecosystem
chronic	occurring over a longer period of time relative to an organism's life
community	a group of interacting organisms (multiple species) that share a common environment in both space and time
composite sample	an analytical sample created by mixing together two or more individual samples; tissue composite samples are composed of two or more individual organisms, and sediment composite samples are composed of two or more individual sediment grab samples
conceptual site model	a description of the links and relationships between contaminant sources, routes of release or transport, exposure pathways, and the ecological receptors at a site
congener	a specific chemical within a group of structurally related chemicals (e.g., PCB congeners)
crustacean	an invertebrate with several pairs of jointed legs, a hard protective outer shell, two pairs of antennae, and eyes at the end of stalks (e.g., crayfish, beach fleas, and sand hoppers)
decapod	a group of crustaceans with an external skeleton and five pairs of walking legs (e.g., crayfish and prawns)

Term	Definition
detritivore	an organism that eats detritus (e.g., Pacific lamprey ammocoetes)
detritus	loose, unconsolidated material, primarily composed of tiny organic fragments (e.g., remains of plants and animals, bacteria, fungi)
ecological risk assessment	a process to evaluate the likelihood that adverse ecological effects might occur or are occurring as a result of exposure to one or more contaminants
dose	the quantity of an contaminant taken in or absorbed at any one time, expressed on a body weight-specific basis; units are generally expressed as mg/kg bw/day
effects assessment	the part of a risk assessment that describes the relationship between exposure to a contaminant and effects on ecological receptors
effect threshold	a level of contaminant exposure of a receptor above which a particular effect is expected to occur or below which no effect is expected to occur
empirical data	data quantified in a laboratory
epibenthic	bottom-dwelling aquatic organisms that live on the sediment or other hard surface
equilibrium partitioning sediment benchmark	sediment concentration derived using the equilibrium partitioning approach to assess the likelihood of significant adverse effects to benthic organisms
equilibrium partitioning approach	based on a theory stating that a nonionic chemical in sediment partitions between sediment organic carbon, porewater, and benthic organisms; at equilibrium, if the concentration in any one phase is known, the concentration in the others can be predicted
exposure assessment	the part of a risk assessment that characterizes the contaminant exposure of a receptor
exposure pathway	physical route by which an contaminant moves from a source to a biological receptor
exposure point	the location or circumstances at which an organism is assumed to contact a contaminant
exposure point concentration	the concentration of a contaminant at the exposure point
exposure scale	size of the area throughout which a receptor might come in contact with an contaminant as determined by home range or foraging habits

Term	Definition
hazard quotient	the quotient of the concentration of a contaminant in an environmental medium divided by the effect threshold
herbivores	organisms that eat primarily plants
high-molecular-weight polycyclic aromatic hydrocarbons (HPAH)	a group of individual PAH compounds with four or more aromatic rings (e.g. fluoranthene, pyrene, chrysene, benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, benzo(g,h,i)perylene)
home range	area over which an individual organism conducts activities throughout its lifespan
infauna	bottom-dwelling aquatic organisms that burrow within a soft substrate
invertivore	organism that eats primarily insects or other invertebrates
line of evidence	a set of data and associated analyses that can be used, either alone or in combination with other lines of evidence, to estimate ecological risks
lipid-normalized concentration	a chemical concentration in biota tissue adjusted for lipid concentration
lowest-observed-adverse-effect level	the lowest level of exposure to a contaminant that causes a measured response that negatively affects an organism
low-molecular-weight polycyclic aromatic hydrocarbons (LPAH)	A group of individual PAH compounds with three or fewer aromatic rings (e.g. naphthalene, 2-methylnaphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene)
macroinvertebrate	invertebrate large enough to be seen by the naked eye
macropthalmia	lamprey juvenile (life-stage following ammocoete)
measurement endpoint	measurable ecological characteristic, either a measure of exposure or a measure of ecological effect that is related to the valued characteristic chosen as an assessment endpoint
meiofauna	very small benthic invertebrates that live among the sand grains below the sediment surface; typically too small to be seen by the naked eye
no-observed-adverse-effect level	the highest level of exposure to a contaminant that does not cause a measured negative response of an organism

Term	Definition
organic carbon-normalized concentration	a chemical concentration in sediment adjusted for organic carbon content
oligochaete	a type of segmented worm that is widely distributed in both sediment and soil
omnivore	an organism that eats both animal and plant matter
pelagic	pertaining to, living in, or occurring in an open water body
periphyton	algae, bacteria, microorganisms (along with organic material) attached to hard substrates (e.g., rock, roots, etc.) that occur in a water body
piscivore	an organism that eats primarily fish
population	a group of organisms belonging to the same species
porewater	water that fills the spaces between grains of sediment
predicted data	data not quantified in a laboratory but estimated using a model
reference threshold	a lower level response (survival or growth) in toxicity tests from a reference area representing the limit of the normal or expected responses in the absence of exposure to site-specific sediment contamination
regression	the statistical relationship between a random variable and one or more independent variables
remediation goal	contaminant-specific requirements that establish acceptable exposure levels for each exposure pathway; may be used as cleanup criteria in a remedial action
riparian	situated or living along the bank of a river or stream
risk	the chance that a specific ecological component experiences a particular adverse effect from exposure to contaminants from a hazardous waste site; the severity of risk increases if the severity of the adverse effect increases or if the chance of the adverse effect occurring increases
risk characterization	a part of the risk assessment process in which exposure and effects data are integrated in order to evaluate the likelihood of associated adverse effects
risk question	a proposed or suspected relationship between an assessment endpoint and its predicted response when exposed to contaminants

Term	Definition
risk threshold	a level of contaminant exposure of a receptor above which a particular effect is expected to occur or below which no effect is expected to occur
screening level risk assessment	a part of the risk assessment in which contaminants of potential concern are identified by comparing maximum contaminant concentrations to screening level effect thresholds
sediment quality guideline	a published sediment concentration used to evaluate sediment quality based on effects to aquatic organisms
site use factor	the fraction of time that a receptor spends foraging at the site relative to the entire home range and based on consideration of seasonal use
special status species	ecological organisms that are protected by federal and/or state regulations or otherwise deemed culturally significant
species	related individuals that share common characteristics and are capable of breeding among themselves and producing fertile offspring
species sensitivity distribution	a mathematical model that attempts to compile effect thresholds for a related set of species
Study Area	the portion of the Lower Willamette River that extends from River Mile 1.9 to River Mile 11.8
sum DDD	the sum of the concentrations of 2,4′-DDD and 4,4′-DDD in an environmental sample
sum DDE	the sum of the concentrations of 2,4′-DDE and 4,4′-DDE in an environmental sample
sum DDT	the sum of the concentrations of 2,4′-DDT and 4,4′-DDT in an environmental sample
threshold sediment concentration	a sediment concentration above which a particular effect is expected to occur or below which no effect is expected to occur
threshold tissue concentration	a tissue concentration above which a particular effect is expected to occur or below which no effect is expected to occur
toxicity threshold	used to define the onset of specific level of adverse effect
trophic level	a feeding level within an ecosystem at which energy is transferred (e.g., herbivores, carnivores)

Term	Definition
total DDx	the sum of the concentrations of the following six individual contaminants in an environmental sample: 2,4′-DDD, 4,4′-DDD, 2,4′-DDE, 4,4′-DDE, 2,4′-DDT and 4,4′-DDT
total PAH	in the context of this BERA, the sum of up to 17 individual PAH compounds analyzed in a sample, or the sum of all groupings of individual PAH compounds by molecular weight, such as LPAH and HPAH
toxic equivalency factor	numerical values developed by the World Health Organization that quantify the toxicity of dioxin, furan, and dioxin-like PCB congeners relative to 2,3,7,8-tetrachlorodibenzodioxin
toxicity reference value	a toxicity threshold that has been used in a risk assessment
transition zone water	porewater associated with the upper layer of the sediment column; may contain both groundwater and surface water
upper confidence limit on the mean	a high-end statistical measure of central tendency

EXECUTIVE SUMMARY

ES.1 INTRODUCTION

This document presents the baseline ecological risk assessment (BERA) for aquatic and aquatic-dependent species exposed to hazardous substances associated with the in-water Willamette River portion of the Portland Harbor Superfund site. The Study Area for the Portland Harbor BERA is defined as the reach of the Lower Willamette River (LWR) between River Mile (RM) 1.9 (as measured upstream from the confluence of the Willamette and Columbia Rivers) and RM 11.8 (Figure ES-1), although data collection for the BERA extends from RM 0.8 to RM 26.4. For the purpose of this BERA, the Willamette River is defined as all areas lower in water surface elevation than the ordinary high water mark (OHWM), including nearshore riparian zone areas not normally inundated by water. Ecological risks to terrestrial and upland species present in locations higher in elevation than the OHWM are evaluated separately as part of the investigations of individual upland source areas under the oversight of the Oregon Department of Environmental Quality (ODEQ) and are not evaluated as part of this BERA.

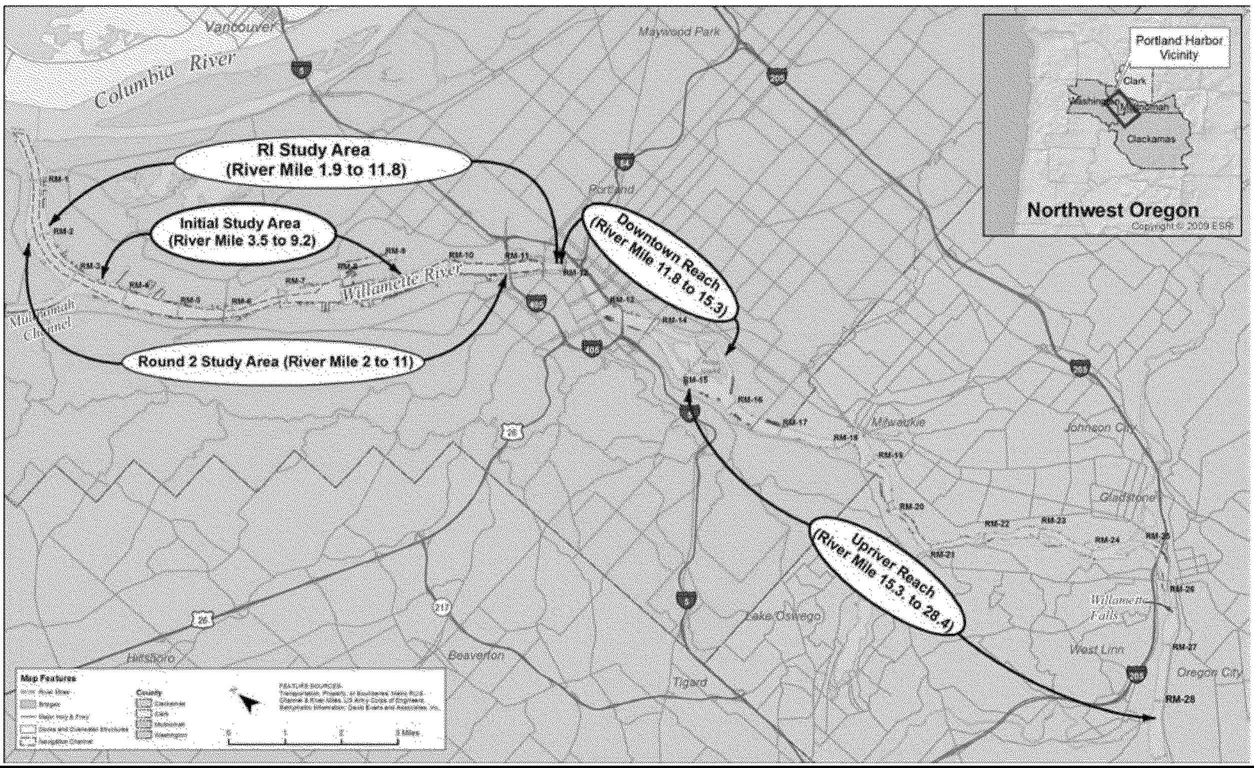

Figure ES-1. Portland Harbor Study Area

ES.2 PURPOSE OF THE BASELINE ECOLOGICAL RISK ASSESSMENT

This BERA evaluates potential threats to the environment at the time when the Portland Harbor remedial investigation (RI) was being conducted. As such, the BERA can be considered as describing ecological risks under the no action alternative of the feasibility study (FS) (EPA 1997a). US Environmental Protection Agency (EPA) risk managers will use the results of the BERA, along with other relevant information, to make decisions regarding remedial cleanup activities needed to protect the environment. Natural resource trustees might also use the information in the BERA during their natural resource damage assessment activities.

The specific overall objectives of the BERA are twofold:

1. Identify the risks posed by chemical contaminants to aquatic and aquatic-dependent ecological receptors associated with the Portland Harbor Study Area under baseline conditions.[1]
2. In the event that unacceptable ecological risks require remedial actions at Portland Harbor, provide information that risk managers can use to make remedial action decisions that are protective of ecological receptors.

ES.3 SITE DESCRIPTION – PHYSICAL CHARACTERIS TICS AND SITE HISTORY

The Willamette River originates within Oregon in the Cascade Mountain Range and flows approximately 187 mi north to its confluence with the Columbia River. The Willamette River is the 12th largest river in the contiguous United States in terms of volume of water discharged, with a flow averaging 33,800 cubic feet per second. Flows vary considerably by season, with the lowest flows occurring during the late summer dry season, typically increasing by 10 times through the winter rainy season.

The LWR extends from RM 0 to Willamette Falls, at approximately RM 26.5. It is a wide, shallow, slow-moving segment with water elevations tidally influenced by as much as 3 ft and tidal reversals occurring during low-flow periods as far upstream as RM 15. The river segment between RM 3 and RM 10 is the primary depositional area of the LWR. The LWR has been extensively dredged to maintain a 40-ft-deep navigation channel from RM 0 to RM 11.6. This segment contains an industrialized area known as Portland Harbor, which contains a multitude of facilities and both private and municipal outfalls (ODEQ 2009).

For over 120 years, Portland Harbor has been an increasingly urbanized and industrialized reach of the Willamette River. What was once a shallow, meandering river has been (since the late 1800s) redirected, filled, or dredged. Today, a federally maintained navigation channel extends nearly bank to bank in some areas. There is little,

[1] Baseline conditions are the conditions represented by the BERA dataset, which includes samples collected between June 2002 and November 2007. The BERA dataset is presented in Attachment 4.

if any, original shoreline or river bottom that has not been modified by the above actions or as a result of them. Much of the riverbank has over-water piers and berths, port terminals and slips, and other engineered features. Shoreline armoring such as riprap makes up approximately half of the Portland Harbor shoreline. Some riverbank areas and adjacent parcels have been abandoned and allowed to revegetate, and beaches have formed along some modified shorelines due to relatively natural processes. A large portion of the upland area adjacent to the Study Area is zoned industrial.

Current uses of the land and water in and along Portland Harbor include:

- Industrial and commercial operations
- Marine activities
- Surface transportation (railroads and roadways)
- Residential
- Recreational use (including parks, boating and fishing)
- Cultural activities
- Agriculture

Human activities have contributed to chemical contamination of the Study Area via multiple pathways, such as direct discharges, overwater releases and spills, stormwater and wastewater outfalls, overland flow, bank erosion, and groundwater discharges. Historical and current activities responsible for the existing contamination include but are not limited to: 1) ship building, repair and dismantling; 2) wood treatment and lumber milling; 3) storage of bulk fuels and manufactured gas production; 4) chemical manufacturing and storage; 5) municipal combined sewer overflows; and 6) stormwater associated with industrial, commercial, transportation, residential, and agricultural land uses. Various chemicals, including but not limited to metals, polychlorinated biphenyls (PCBs), dioxins/furans, pesticides, polycyclic aromatic hydrocarbons (PAHs) from petroleum and other sources, and phthalates, have been released to the river over many decades.

Historical contamination in the Willamette River led EPA to perform a preliminary assessment and site investigation in 1997. Results from this investigation led to the listing of the Portland Harbor Superfund site on the National Priorities List in December 2000. In 2001, 10 parties, who collectively became known as the Lower Willamette Group (LWG),[2] signed an Administrative Order on Consent with EPA in which they agreed to perform the RI/FS for the Portland Harbor Superfund Site (Site). This BERA is a part of

[2] The 10 organizations within the LWG that signed the 2001 Administrative Order on Consent with EPA are Arkema, Inc.; Chevron USA, Inc.; Gunderson LLC; NW Natural; City of Portland; Port of Portland; TOC Holdings Co.; ConocoPhillips Co.; Union Pacific Railroad Co.; and Evraz Oregon Steel.

the RI report (Appendix G) and informs the FS. The LWG is a subset of the approximately 150 potentially responsible parties identified by EPA for the Site.

Given the large number and wide variety of historical and present-day contaminant sources; the multitude of chemicals and hazardous substances released; the differences in the composition, volume, and mass of hazardous substances released from the various sources; and the multiple locations within and outside of the Study Area from which contaminants have been released, it is not surprising that some contaminants have elevated concentrations throughout much if not all of the Study Area while many more contaminants are not distributed Study Area-wide. Instead, many contaminants have elevated concentrations at only one or a few locations in the Study Area. This is reflected in the distribution and variability in the number of contaminants posing potentially unacceptable risks[3] in any specific section of the Study Area, as well as the areal extent and magnitude of ecological risks from exposure to each hazardous substance.

ES.4 SITE DESCRIPTION – BIOLOGICAL

The numerous aquatic and aquatic-dependent organisms that use the Willamette River can be divided into the following general groups: invertebrates, fishes, birds, mammals, amphibians, reptiles, and aquatic plants. All organisms present within the Study Area contribute to the ecological functioning of the river. Riverine invertebrates are predominantly benthic (i.e., living in or associated with river bottom substrates), using substrates such as fine-grained sediment, gravel and cobble, plant roots, and large woody debris. The benthic invertebrate community within the LWR is dominated by small benthic organisms, many of which feed on organic material imported from upstream areas.

The Willamette River is an important migration corridor for anadromous fishes, including Pacific lamprey and multiple salmon species, and provides habitat for approximately 50 resident fish species. Fish present in the river can be grouped into four major feeding guilds: omnivores/herbivores, invertivores, piscivores, and detritivores. Over 20 commonly occurring aquatic-dependent bird species use habitats and feed on aquatic species within the Study Area. The trophic representation of these birds is broad and includes herbivores, carnivores and omnivores, sediment-probing invertivores and omnivores, and piscivores. Seven aquatic or semi-aquatic mammals use or may use the river within the Study Area, including herbivores, omnivores, and piscivores.

[3] The phrase "contaminant posing potentially unacceptable risk" is used throughout this BERA instead of the more commonly used phrase "contaminant of (ecological) concern" (COC). Within various EPA guidance documents, the phrases chemical of concern and contaminant of concern have at least six different definitions, making them somewhat imprecise terms. The contaminants posing potentially unacceptable risk at the end of the BERA are forwarded into the FS. It is the responsibility of the EPA risk manager to ultimately define the unacceptable ecological risks, which may become a basis for remedial actions to prevent, mitigate, or otherwise respond to or remedy any release or threatened release of hazardous substances, pollutants, or contaminants at or from the Site.

Section 2.0 of the BERA provides extensive details about biological conditions within the Study Area, including lists of the species sampled or known to be present. Section 2.0 also provides additional information on physical conditions within the Study Area.

ES.5 ECOLOGICAL RISK ASSESSMENT PROCEDURE

Procedures used in this BERA to evaluate the nature, severity, and areal extent of risks to ecological receptors in Portland Harbor were based on the guidance provided in the 8-step, iterative approach to ecological risk assessment (ERA) described in the EPA (1997a) *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments – Interim Final*. The 8 steps identified in this guidance are as follows:

1. Screening Level Problem Formulation and Ecological Effects Evaluation 2. Screening Level Preliminary Exposure Estimate and Risk Calculation	Screening-level ERA (SLERA)
3. Baseline Risk Assessment Problem Formulation 4. Study Design and Data Quality Objectives 5. Field Verification of Sampling Design 6. Site Investigation and Analysis of Exposure and Effects 7. Risk Characterization	BERA
8. Risk Management	Risk management

No guidance document, no matter how detailed, can describe the procedures needed to fully evaluate ecological risks at a site as complex as Portland Harbor. In order to accommodate the needs of this BERA, numerous Portland Harbor site-specific ERA procedures, methodologies, memoranda, and intermediate data reports and analyses have been developed and presented in documents prepared by the LWG in collaboration with and oversight of EPA and its federal, state, and tribal partners. Among these documents are the *Portland Harbor Remedial Investigation/Feasibility Study (RI/FS) Programmatic Work Plan* (Integral et al. 2004b), the draft *Portland Harbor RI/FS, Ecological Preliminary Risk Evaluation* (Windward 2005a), and the *Problem Formulation for the Baseline Ecological Risk Assessment at the Portland Harbor Site* (EPA 2008j), which is included in this BERA as Attachment 2.

ES.6 CHEMICAL CONTAMINANT AND TOXICITY DATA AVAILABLE FOR ECOLOGICAL RISK ASSESSMENT USE

The BERA dataset is a subset of the complete RI dataset and includes only those samples relevant to ecological exposure pathways. It does not contain sediment data from a depth greater than 30.5 cm (12 in.) below the sediment surface; nor does it include transition zone water (TZW) (i.e., sediment porewater that is composed of some percentage of both groundwater and surface water) collected more than 38 cm (15 in.) below the sediment surface. The deeper sediment and TZW samples were excluded from the BERA exposure assessment because the likelihood that any species present in Portland Harbor comes into contact with or ingests such material is extremely low.

Chemical contaminant data available for use in the BERA were collected during three rounds of sampling. Round 1 sampling, which focused on the collection of biota (tissue) samples, was conducted in 2002. Round 2 sampling began with multiple field efforts in 2004 and focused on the characterization of surface and subsurface sediment quality. Round 3 sampling occurred between 2006 and early 2008 and included the collection of surface water, biota, sediment upstream and downstream of the Study Area, suspended sediment (in-river sediment traps), and stormwater samples. Round 3 sampling also filled data gaps related to site characterization, ecological and human health risks, upriver background contaminant concentrations, and the FS.

As a result of the systematic approach that was used to generate Study Area data, the Portland Harbor BERA is supported by an extensive, high-quality database that features the concentrations of numerous chemicals in multiple environmental media types (i.e., sediment, water, and bird eggs and tissues from multiple fish and invertebrate species). In addition to this chemical dataset, a sizable number of sediment toxicity test results, which directly measured the effect of sediment constituents on the survival and growth of two benthic species were available. The numbers of samples in the BERA dataset are summarized in Table ES-1.

Table ES-1. Numbers of Samples Chemically Analyzed During the Portland Harbor BERA

Location	Surface Sediment	Sediment Toxicity Tests	Fish and Invertebrate Tissue	Bird Eggs	Surface Water	Transition Zone Water
Study Area (RM 1.9 – RM 11.8)	1,469	269	315	5	313	192
Downstream reach (RM 0 – RM 1.9)	21	0	5	0	0	0
Multnomah Channel	7	0	0	0	0	0
Downtown reach (RM 11.8 – RM 15.3)	17	2	6	0	0	0
Upstream (RM 15.3 – RM 28.4)	22	22	18	5	0	0

BERA – baseline ecological risk assessment
RM – river mile

In addition, a study was conducted to address the question of whether the use of surrogate species in the risk assessment would be protective of lamprey ammocoetes. The study evaluated the acute toxicity of six chemicals representing six different toxic modes of action (Andersen et al. 2010). Results indicated that the use of surrogates was protective of lamprey at this life stage.

ES.7 SCREENING-LEVEL ECOLOGICAL RISK ASSESSMENTFINDINGS

The SLERA (which encompass Steps 1 and 2 of the above 8-step process and is included as Attachment 5 of this BERA) identified numerous contaminants of potential concern (COPCs) whose concentrations exceeded conservative screening-level effect thresholds in sediment, water, tissue, and ingested dietary doses. The possibility of ecological risks from hazardous substances within Portland Harbor could not be discounted based on the SLERA results so, in accordance with EPA ERA policy and guidance, the more comprehensive baseline ecological risk evaluations described in this BERA were initiated. This BERA presents the findings of Steps 3 through 7 of the 8-step ERA process.

ES.8 BERA PROBLEM FORMULATION

According to EPA (1997a) guidance, a BERA problem formulation (Step 3 of the 8-step EPA ERA process) generally consists of the following five tasks:

- Refinement of the preliminary list of COPCs for the site
- Further characterization of the potential ecological effects of COPCs on Study Area receptors
- Review and refinement of information on the fate and transport of COPCs, on potential exposure pathways, and on the receptors potentially at risk
- Selection of assessment endpoints (environmental values to be protected)
- Development of a conceptual site model (CSM) with testable hypotheses (or risk questions) that the BERA will address

The products of the problem formulation are used to select measurement endpoints (what is actually measured at a site) and develop the ERA work plan and sampling and analysis plans (SAPs) for the Study Area in Step 4 of EPA's ERA process. In practice, Steps 3 and 4 of the 8-step EPA ERA process are often, as was the case for Portland Harbor, performed concurrently.

ES.8.1 Problem Formulation – Identification of COPCs

The refined screen, which resulted in the final COPC list evaluated in the BERA, is presented in Chapter 5 and Attachment 5 of this BERA. Table ES-2 presents the number of COPCs carried forward from the refined screen to the risk characterization step for each environmental medium evaluated.

Table ES-2. Number of COPCs Evaluated in the BERA

Medium or Diet	No. of COPCs	No. of Chemicals without Screening-Level TRVs
Sediment	67	106
Invertebrate tissue	18	23
Fish tissue	16	8
Fish dietary dose	9	11
Bird dietary dose	23	19
Mammal dietary dose	12	11
Bird egg tissue	5	0
Surface water	14	19
TZW	58	14

BERA – baseline ecological risk assessment
COPC – contaminant of potential concern
TRV – toxicity reference value
TZW – transition zone water

Table ES-2 also lists the number of chemicals within each medium for which screening-level or refined screen toxicity reference values (TRVs) could not be identified or derived. Risks associated with these chemicals were evaluated if alternative methods were available to derive TRVs in the BERA; otherwise risks from these chemicals could not be quantified. Unquantified ecological risks from contaminants without baseline TRVs are likely the primary source of uncertainty in this BERA that could lead to under-estimating ecological risks within Portland Harbor because most other types of uncertainty are handled by making conservative assumptions, which tends to build a margin of safety into ecological risk estimates.

The types or groups of contaminants identified as COPCs in the BERA are summarized in Table ES-3. Screening resulted in the identification of a combined 104 COPCs for benthic invertebrates across four media types (i.e., sediment, invertebrate tissue, surface water, and TZW). A combined 74 fish COPCs were identified when the results of the screening of all fish species analyzed were compiled, based on the summing the COPCs across all media and for the dietary line of evidence (LOE). Twenty-three COPCs were identified for birds through two LOEs, and twelve COPCs were identified for mammals based on one LOE. Finally, 64 COPCs were identified for amphibians and aquatic plants through two LOEs. More detailed information regarding the final COPC list for the various receptors is presented in Section 5.2 (benthic invertebrates), Section 5.3 (fish), Section 5.4 (birds and mammals) and Section 5.5 (aquatic plants and amphibians).

Table ES-3. COPCs Forwarded to the BERA after Screening

Receptor Group	Media Evaluated	Number of COPCs	COPCs
Benthic invertebrates, bivalves, decapods	Surface water, TZW, sediment, tissue	104	20 metals, 2 butyltins, 21 individual PAHs or PAH sums, 4 phthalates, 12 SVOCs, 6 phenols, 16 pesticide or pesticide sums, total PCBs, 2,3,7,8-TCDD (dioxin), 16 VOCs, 3 total TPH fractions, cyanide, perchlorate
Fish	Surface water, TZW, sediment, diet, tissue	74	19 metals, 4 butyltins, 17 individual PAHs or PAH sums, BEHP, 3 SVOCs, total PCBs, dioxin TEQ, total TEQ, 7 pesticide or pesticide sums, 18 VOCs, cyanide, perchlorate
Birds and mammals	Diet (birds and mammals), bird eggs	23 (birds) 12 (mammals)	11 metals, 3 individual PAHs or PAH sums, 2 phthalates, total PCBs, dioxin TEQ, PCB TEQ, total TEQ, 3 pesticide or pesticide sums
Aquatic plants, amphibians	Surface water, TZW	64	15 metals, monobutyltin, 16 individual PAHs, BEHP, 3 SVOCs, total PCBs, 6 pesticide or pesticide sums, 18 VOCs, gasoline-range hydrocarbons, cyanide, perchlorate

BEHP – bis(2-ethylhexyl)phthalate
BERA – baseline ecological risk assessment
COPC – contaminant of potential concern
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
TCDD – tetrachlorodibenzo-*p*-dioxin
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
TZW – transition zone water
VOC – volatile organic compound

ES.8.2 Problem Formulation – Ecological Effects Characterization

Ecological effects characterization within the BERA problem formulation resulted in the final list of TRVs and sediment quality values (SQVs) for the various environmental media and samples evaluated. TRVs and SQVs are contaminant concentrations in media (i.e., sediment, water, tissue, or diet) of ecological receptors, which, if not exceeded, describe contaminant concentrations considered to pose no or only acceptable levels of ecological risk.

A floating percentile model (FPM) and logistic regression model (LRM) (both of which are presented in BERA Attachment 6) used site-specific synoptic sediment toxicity chemistry data to develop SQVs that provided relatively reliable predictions of sediment toxicity test results at 293 sediment sampling locations for which sediment toxicity tests were conducted (269 sampling locations in the Study Area and 24 sampling locations in the LWR upstream from the Study Area). The SQVs were then used to predict sediment toxicity at Portland Harbor sediment sampling locations for which sediment toxicity tests were not conducted.

The tissue residue approach (presented in Attachment 9) was used to derive contaminant concentrations in fish and aquatic invertebrate tissue, which, if exceeded, would define tissue contaminant concentrations posing potentially unacceptable ecological risks.

Although screening-level ecological risk benchmarks for contaminants in aquatic life tissue have been available for some time, this BERA represents perhaps the first effort to derive numerous baseline tissue TRVs.

The remaining TRVs used in this BERA were taken from either existing compendia of environmental quality guidelines or directly from the original scientific literature.

ES.8.3 Problem Formulation – COPC Fate and Transport, Exposure Pathways, and Receptors at Risk

Contaminant sources and distribution within Portland Harbor and their environmental fate and transport (Chapters 4, 5 and 6, respectively, of the RI report), as well as exposure pathways and the identification of ecological receptors potentially at risk, had largely been defined prior to the development of the BERA problem formulation (EPA 2008j). Therefore, this stage of the problem formulation focused on identifying a subset of species for which ecological risks would be evaluated in the BERA.

Given that Portland Harbor is inhabited by hundreds if not thousands of species, the majority of which are lower-trophic-level species, such as algae and benthic invertebrates, it is not feasible to quantify risks to every species within the Study Area. The primary selection criteria for ecological receptors were: 1) that they represent the feeding guilds present at Portland Harbor; 2) that the receptor use the same habitat as other similar species; 3) that the receptor be susceptible to contaminants; and 4) that the receptor be ecologically, culturally, or economically significant. The term feeding guild refers to a group of species that share similar feeding strategies or diets, thus resulting in a similar potential for contaminant exposure as other members of the guild.

ES.8.4 Problem Formulation – Assessment Endpoint Selection

Perhaps the most important planning step of the entire BERA is the development of the assessment endpoints, risk questions, measurement endpoints, and LOEs to be assessed in a BERA. This is because combined, they establish the goals, breadth, and focus of the BERA. Brief definitions of the above four terms are as follows:

- **Assessment endpoints** – explicit expressions of environmental values to be protected
- **Risk questions** – proposed or suspected relationships between assessment endpoints and their predicted responses when exposed to contaminants
- **Measurement endpoints** – measurable ecological characteristics, either measures of exposure or measures of ecological effect that are related to the valued characteristics chosen as assessment endpoints
- **Line of evidence** – a set of data and associated analyses that can be used, either alone or in combination with other LOEs, to estimate ecological risks

For each assessment endpoint, risk questions and testable hypotheses are developed. Risk questions provide the basis for defining measurement endpoints that are evaluated with information collected during studies designed and performed as part of the RI of the site. Each measurement endpoint is evaluated with one or more LOEs.

An example of the relationship between assessment endpoints, risk questions, target ecological receptors, measurement endpoints, and LOEs is provided below for the aquatic plant assessment endpoint.

- **Assessment endpoint** – Survival, reproduction, and growth of aquatic plants
- **Risk questions/testable hypotheses –** Are contaminant concentrations in Willamette River surface water or sediment TZW from Portland Harbor sediment greater than the toxicity thresholds for the survival, growth, or reproduction of aquatic plants?
- **Target ecological receptors –** Phytoplankton, periphyton, and macrophytes (no specific plant species were identified as target receptors)
- **Measurement endpoint** – Water contaminant concentrations compared with ambient water quality criteria (AWQC) or TRVs
- **LOE No. 1** – Surface water contaminant concentrations compared with literature-based TRVs or AWQC that protect aquatic plant survival, growth, and reproduction
- **LOE No. 2** – TZW contaminant concentrations compared with literature-based TRVs or AWQC that protect aquatic plant survival, growth, and reproduction

The Portland Harbor BERA evaluated 13 assessment endpoints. Twelve of the thirteen assessment endpoints took the form of "survival, growth, and reproduction of" a group of species that shared a habitat, taxonomic category, or feeding guild.

The 12 assessment endpoints with the form "survival, growth, and reproduction of…." were:

- Aquatic plants
- Benthic macroinvertebrates
- Bivalves
- Decapods
- Invertivorous fish
- Omnivorous fish
- Piscivorous fish
- Amphibians
- Piscivorous birds

- Omnivorous birds
- Invertivorous birds
- Aquatic-dependent mammals

The 13th assessment endpoint was:

- Survival and growth of detritivorous fish (Pacific lamprey ammocoetes)

Reproduction was not evaluated for Pacific lamprey ammocoetes because this is not the reproducing life stage of the lamprey.

The full list of 24 target ecological receptors, 31 measurement endpoints, and 55 LOEs evaluated is presented in Attachment 2.

ES.8.5 Problem Formulation – Conceptual Site Model Development

The last step of the problem formulation, the development of the CSM, was also largely completed prior to the commencement of work on the BERA problem formulation (EPA 2008j). A CSM describes relationships between contaminants and the resources potentially affected by their release.

The routes of exposure are the means by which contaminants are transferred from a contaminated medium to an ecological receptor. The most significant pathways by which ecological receptors may be exposed to Portland Harbor COPCs are:

- **Aquatic plants** – Root uptake; direct contact with sediment, surface water, and TZW
- **Benthic invertebrates** – Direct contact with sediment, surface water, and TZW; ingestion of sediment and food
- **Fish** – Direct contact with sediment, surface water, and TZW; ingestion of sediment and food
- **Birds and mammals** – Ingestion of soil, sediment, and food
- **Amphibians** – Direct contact with surface water and TZW; ingestion of sediment and food

ES.9 STUDY DESIGN AND DATA QUALITY OBJECTIVE PROCESS

Section 4.0 describes the individual sediment, water, and biota sampling events that were carried out during the BERA. All of the sampling and chemical analyses performed to obtain the data used in the BERA followed procedures were defined in the ERA work plan (Integral et al. 2004b) and the numerous SAPs for various tasks. The data management rules (including data reduction, data usability, and data quality) are described in detail in Section 2.0 of the draft final RI (Integral et al. 2011).

The data quality objective process used during the development of the BERA SAPs describes a series of planning steps that were employed to ensure that the type, quantity, and quality of environmental data collected for the BERA were adequate to support the intended uses of the data.

ES.10 FIELD VERIFICATION OF SAMPLING DESIGN

Step 5 of the 8-step ecological risk assessment process verifies that the selected assessment endpoints, testable hypotheses, exposure pathway model, measurement endpoints, and study design from Steps 3 and 4 are appropriate and implementable at the Study Area. By verifying the study design, alterations can be made to the study design and/or implementation if necessary. These changes ensure that the ERA meets its objectives.

Among the multiple changes made to various study plans during the three rounds of field sampling for the BERA, two are noteworthy. The original 2001 Administrative Order on Consent defined the Initial Study Area as RM 3.5 to RM 9.2. As more information became available about the Site, the need to expand the Study Area to answer questions identified not only during the BERA process but other RI tasks resulted in the expansion of the Study Area to its current definition of RM 1.9 to RM 11.8.

The availability of radiotelemetry information on the movement of juvenile salmonids, smallmouth bass, and northern pikeminnow (Friesen 2005) in the Study Area allowed the development of site-specific home range estimates for these species. Site-specific home range estimates for aquatic species are rare at Superfund sites, and the availability of such information for several target ecological receptors informed field sampling plans (FSPs) and also allowed for the definition of species-specific contaminant exposure concentrations for these species.

ES.11 SITE INVESTIGATION AND ANALYSIS OF EXPOSURE AND EFFECTS

Information collected during the site investigation (Step 6 of the 8-step EPA ERA process) was used to characterize exposures and ecological effects. The site investigation included all of the field sampling and surveys that were conducted as part of the ERA. The site investigation and analysis of exposure and effects followed the RI/FS programmatic work plan (Integral et al. 2004b) and the numerous SAPs and FSPs developed and tested in Steps 4 and 5.

ES.11.1 Ecological Exposure Assessment

To ensure conservatism (i.e., protectiveness) in the BERA, all COPCs were first evaluated on a sample-by-sample basis. The exposure of benthic invertebrates was assessed based on contaminant concentrations in individual samples of sediment, water, and TZW throughout the BERA, inasmuch as settled individuals of these species have little or no ability to move within the Study Area.

Because a sample-by-sample exposure area is not ecologically relevant for the mobile receptors evaluated in the BERA (i.e., fish, birds, and mammals), COPCs for mobile species were then evaluated at an exposure scale that was ecologically relevant for each specific receptor. The exposure area for mobile receptors was defined as the home range of each target ecological receptor evaluated. With the exception of the fish species for which site-specific movement and home range information was available, home ranges were derived from the published ecological literature. For dietary risks to fish and wildlife, exposure estimates were also determined for a diet consisting of multiple prey species using prey portions reported in the literature. Exposure concentrations were based both on contaminant concentrations quantified in the analytical laboratory (i.e., empirical concentrations) and, for some LOEs (i.e., the tissue-residue LOE and the dietary LOE for shorebirds), on predicted values.

ES.11.2 Ecological Effects Assessment

The effects assessment involved two general approaches. For most ecological receptors, the effects of COPCs were assessed by comparing contaminant concentrations in each environmental medium with contaminant- and medium-specific TRVs or site-specific SQVs. Consistent with the problem formulation, for all receptors and receptor groups evaluated at the community or population level, lowest-observed-adverse-effect level (LOAEL) TRVs were used. No-observed-adverse-effect level (NOAEL) TRVs were used for receptors evaluated at the organism level (i.e., juvenile Chinook salmon, Pacific lamprey ammocoetes).

The second effects assessment approach used sediment toxicity bioassays as a direct measure of the effects of sediment contaminant mixtures on the survival and biomass of benthic invertebrates in the laboratory. Two predictive models (the FPM and LRM) were used to develop site-specific SQVs. The goals of both models were to predict benthic toxicity for locations at which there were no measured toxicity data and to define site-specific SQVs based on associations between measured sediment chemistry and measured sediment toxicity.

ES.12 RISK CHARACTERIZATION

Risk characterization (Step 7 of the EPA (1997a) 8-step ecological risk process) is the final phase of the BERA itself. During risk characterization, information from the exposure assessment and ecological effects assessment are combined into descriptions of the likelihood of unacceptable ecological risk to the assessment endpoints established in the problem formulation (Step 3 of the 8-step process). The risk characterization includes information on the contaminants posing potentially unacceptable risk, which ecological receptors are at risk, the media and exposure pathways in which contaminants posing potentially unacceptable risks are found, the magnitude of the risks, and the location(s) of risks within the Study Area.

In addition to the quantitative calculations performed to estimate risks, the risk characterization also discusses the level of agreement among the multiple LOEs used to assess risks to the assessment endpoints, the relative strengths and weaknesses of each LOE, the ecological significance of identified risks, and the uncertainties associated with the risk assessment conclusions.

Direct evidence of causality, if available, provides the strongest LOE for a site posing potentially unacceptable ecological risks. Sediment toxicity tests were performed to evaluate adverse effects of Portland Harbor sediment on survival and biomass (a combined survival and growth endpoint) of larvae of the aquatic insect *Chironomus dilutus* and juveniles of the amphipod *Hyalella azteca*. Results are summarized in Table ES-4. These toxicity tests demonstrated that the exposure of these animals to sediment from some locations within Portland Harbor resulted in increased mortality and/or reduced biomass of these two species within 10 to 28 days – a direct measure of sediment toxicity to benthic invertebrates within the Portland Harbor Study Area.

Table ES-4. Sediment Toxicity Test Results

Test	Level 0 (No Toxicity)	Level 1 (Low Toxicity)	Level 2 (Moderate Toxicity)	Level 3 (Severe Toxicity)
Chironomus survival	210 of 256	12 of 256	9 of 256	25 of 256
Chironomus biomass	190 of 256	24 of 256	7 of 256	35 of 256
Hyalella survival	224 of 256	15 of 256	2 of 256	15 of 256
Hyalella biomass	143 of 256	47 of 256	42 of 256	24 of 256

The moderate and severe levels of toxicity were not randomly scattered throughout the Study Area. Instead, most samples and locations eliciting multiple instances of moderate and severe toxicity tended to be clustered in several areas (see Section 6), especially areas between RM 5.9 and RM 7.8 on the west side of the river. Other areas with “clusters” of benthic toxicity included:

- International Slip
- Between RM 3.7 and RM 4.2, west side of river
- Between RM 4.8 and RM 5.2, west side of river
- Willamette Cove
- Near the mouth of Swan Island Lagoon
- RM 8.7 to RM 8.8, west side of river

Other individual samples and locations exhibited toxicity to *Chironomus* and *Hyalella*. However, the above areas are those within the Study Area where the greatest toxicity was found. A weight-of-evidence analysis identified 17 benthic areas of concern (AOCs) within the Study Area consistent with the potential benthic risk areas identified in the BERA. Combined, the above areas can be estimated to cover between 4 and 8% of the total surface area of sediment within the Study Area. Contaminants found at elevated concentrations relative to SQVs in these areas are those most likely to be posing ecological risks to benthic invertebrates.

Most risk characterizations in the BERA were made using the hazard quotient (HQ). An HQ is calculated by dividing the exposure point concentration by the selected TRV. HQs can also be comparisons of ingested dietary doses of contaminants with dietary TRVs or comparisons of measured COPC concentrations in prey of target ecological receptors with threshold tissue concentrations in prey species.

COPCs for which the HQ was ≥ 1.0 were identified as contaminants posing potentially unacceptable risk at the conclusion of the BERA. The potential for unacceptable risk becomes increasingly large as the HQ value increases, although the increase is not necessarily linear (e.g., a sample with an HQ = 2.0 does not necessarily have twice the risk of a sample with an HQ = 1.0).

The complete list of COPCs posing potentially unacceptable ecological risks to the BERA assessment endpoints, the exposure pathways by which COPCs pose potentially unacceptable risks, and sections of the BERA where additional details can be found regarding the magnitude of risks, risks to specific target ecological receptor species, and locations within the Study Area where risks are found are presented in Table ES-5.

Table ES-5. COPCs Posing Potentially Unacceptable Ecological Risks within the Portland Harbor Study Area

Assessment Endpoint	Exposure Pathway	COPCs with HQ ≥ 1.0	Additional Details
Aquatic plants, amphibians	Surface water	Benzo(a)anthracene, benzo(a)pyrene, BEHP, naphthalene, total DDx, total PCBs,[a] zinc	Sections 9-1 (amphibians) and 10-1 (aquatic plants)
	TZW	1,2,4-Trimethylbenzene, 1,2-dichlorobenzene, 2-methylnaphthalene, 4,4′-DDT, acenaphthene, anthracene, barium, benzo(a)anthracene, benzo(a)pyrene, cadmium, carbon disulfide, chlorobenzene, chloroethane, chloroform, copper, cyanide, ethylbenzene, fluorene, gasoline fraction (aliphatic) C4 – C6, gasoline fraction (aliphatic) C10 – C12, iron, isopropylbenzene, lead, magnesium, manganese, naphthalene, nickel, perchlorate, phenanthrene, potassium, sodium, toluene, total DDx, zinc	Sections 9-2 (amphibians) and 10-1 (aquatic plants)
Benthic invertebrates, bivalves, decapods	Sediment	2,4′-DDD, 2-methylnaphthalene, 4,4′-DDD, 4,4′-DDE, 4,4′-DDT, 4-methylphenol, acenaphthene, acenaphthylene, ammonia,[b] anthracene, Aroclor 1254[c], arsenic[c], benzo(a)anthracene, benzo(a)pyrene,[c] benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, benzyl alcohol, cadmium, carbazole, chlordane (cis and trans),[c] chromium, chrysene, cis-chlordane, copper, dibenzo(a,h)anthracene, dibenzofuran, dibutyl phthalate, dieldrin, diesel-range petroleum hydrocarbons, endrin, endrin ketone, fluoranthene, fluorene, gasoline-range hydrocarbons,[d] heptachlor epoxide,[c] indeno(1,2,3-cd)pyrene, lead, lindane (γ-HCH),[c] mercury, naphthalene,[c] nickel,[c] phenanthrene, phenol, pyrene, residual-range hydrocarbons,[e] silver, sulfide,[b] sum DDD, sum DDE, sum DDT, total chlordane,[c] total DDx, total endosulfan, total HPAH, total LPAH, total PAH, total PCBs, TBT, zinc,[c] β-HCH, δ-HCH	Sections 6-2 and 6-3
	Surface water	4,4′-DDT,[a] benzo(a)anthracene, benzo(a)pyrene, BEHP, ethylbenzene, naphthalene, total DDx, total PCBs,[a] trichloroethene, zinc	Section 6-5
	TZW	1,1-Dichloroethene, 1,2,4-trimethylbenzene, 1,2-dichlorobenzene, 1,3,5-trimethylbenzene, 1,4-dichlorobenzene, 2-methylnaphthalene, 4,4′-DDT, acenaphthene, anthracene, barium, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, beryllium, cadmium, carbon disulfide, chlorobenzene, chloroethane, chloroform, chrysene, cis-1,2-dichloroethene, cobalt, copper, cyanide, dibenzo(a,h)anthracene, dibenzofuran, ethylbenzene, fluoranthene, fluorene, gasoline fraction (aliphatic) C4 – C6, gasoline fraction (aliphatic) C6 – C8, gasoline fraction (aliphatic) C10 – C12, gasoline fraction (aromatic) C8 – C10, indeno(1,2,3-cd)pyrene, iron, isopropylbenzene, lead, m,p-xylene, magnesium, manganese, naphthalene, nickel, o-xylene, perchlorate, phenanthrene, potassium, pyrene, sodium, toluene, total DDx, total xylenes, trichloroethene, vanadium, zinc	Section 6-6
	Tissue	4,4′-DDD, arsenic, BEHP, copper, total DDx, total PCBs, TBT, zinc	Section 6-4
Fish	Surface water	4,4′-DDT,[a] benzo(a)anthracene, benzo(a)pyrene, BEHP, ethylbenzene, naphthalene, total DDx, total PCBs,[a] trichloroethene, zinc	Section 7-3
	TZW	1,1-Dichloroethene, 1,2,4-trimethylbenzene, 1,2-dichlorobenzene, 1,3,5-trimethylbenzene, 1,4-dichlorobenzene, 2-methylnaphthalene, 4,4′-DDT, acenaphthene, anthracene, barium, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene,	Section 7-4

Table ES-5. COPCs Posing Potentially Unacceptable Ecological Risks within the Portland Harbor Study Area

Assessment Endpoint	Exposure Pathway	COPCs with HQ ≥ 1.0	Additional Details
		beryllium, cadmium, carbon disulfide, chlorobenzene, chloroethane, chloroform, chrysene, cis-1,2-dichloroethene, cobalt, copper, cyanide, dibenzo(a,h)anthracene, dibenzofuran, ethylbenzene, fluoranthene, fluorene, gasoline fraction (aliphatic) C4 – C6, gasoline fraction (aliphatic) C6 – C8, gasoline fraction (aliphatic) C10 – C12, gasoline fraction (aromatic) C8 – C10, indeno(1,2,3-cd)pyrene, iron, isopropylbenzene, lead, m,p-xylene, magnesium, manganese, naphthalene, nickel, o-xylene, perchlorate, phenanthrene, potassium, pyrene, sodium, toluene, total DDx, total xylenes, trichloroethene, vanadium, zinc	
	Fish tissue	Antimony, BEHP, copper, lead, total DDx, total PCBs	Section 7-1
	Diet	Cadmium, copper, mercury, TBT	Section 7-2
Birds	Diet	Aldrin, benzo(a)pyrene, copper, dibutyl phthalate, lead, sum DDE, total DDx, total dioxin/furan TEQ, total PCBs, total PCB TEQ, total TEQ	Section 8-1
	Bird egg tissue	Total dioxin/furan TEQ, total PCBs, total PCB TEQ, total TEQ	Section 8-2
Mammals	Diet	Aluminum, lead, total dioxin/furan TEQ, total PCBs, total PCB TEQ, total TEQ	Section 8-1

[a] Identified as a COPC (HQ ≥ 1,0) when the AWQC TRV was adopted; not identified as a COPC (HQ < 1.0) when the alternative TRV was adopted. These chemicals are not included in the total counts of COPCs with potentially unacceptable ecological risk unless they were identified as a COPC for another LOE.

[b] Ammonia and sulfide in bulk sediment exceeded SLs but are not included in the total counts of COPCs with potentially unacceptable ecological risk.

[c] Identified as a COPC based on concentrations that exceeded the sediment PEC and/or PEL [see Section 6.3]; chemical was not identified as a COPC based on the FPM or LRM predicted toxicity LOE. These chemicals are not included in the total counts of COPCs with potentially unacceptable ecological risk unless they were identified as a COPC for another LOE (e.g., arsenic is identified as a COPC with potentially unacceptable risk for benthic invertebrates based on the tissue LOE and is therefore included in the total count of COPCs).

[d] Identified as a COPC based on concentrations that exceeded the TPH SQG (i.e., the chemical was not identified as a COPC for any other benthic sediment evaluation).

[e] Identified as a COPC based on concentrations that exceeded the TPH SQG; chemical was not included in the COPC counts if identified as a COPC based only on the TPH SQG exceedance.

AWQC – ambient water quality criteria
BEHP – bis(2-ethylhexyl) phthalate
COPC – chemical of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
FPM – floating percentile model
HCH – hexachlorocyclohexane
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
HQ – hazard quotient
LOE – line of evidence
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
LRM – logistic regression model
PCB – polychlorinated biphenyl
PEC – probable effects concentration
PEL – probable effects level
SL – screening level
SQG – sediment quality guideline
TBT – tributyltin
TEQ – toxic equivalent
total DDx – sum of all six DDT isomers (2,4′-DDD, 4,4′-DDD, 2,4′-DDE, 4,4′-DDE, 2,4′-DDT and 4,4′-DDT)
TPH – total petroleum hydrocarbons
TRV – toxicity reference value
TZW – transition zone water

Risk characterization would not be complete without mention of the LOEs for which no ecological risks were identified. Table ES-6 lists the LOEs for several assessment endpoints for which no ecological risks were identified.

Table ES-6. BERA LOEs for which No Potentially Unacceptable Ecological Risks Were Identified

Assessment Endpoint	Measurement Endpoint	Line of Evidence
Survival, growth, reproduction of benthic invertebrates	Benthic invertebrate tissue data compared to tissue TRVs	Field-collected epibenthic macroinvertebrate tissue concentration (from Hester-Dendy samplers) relative to tissue TRVs
Survival, growth, reproduction of bivalves	Sediment toxicity testing to empirically assess adverse effects	*Corbicula fluminea* survival in 28-day bioaccumulation test
Survival, growth, reproduction of omnivorous fish	Concentrations in surface water compared with water TRVs	
Survival, growth, reproduction of detritivorous fish	Concentrations in surface water compared with water TRVs	

BERA – baseline ecological risk assessment
LOE – line of evidence
TRV – toxicity reference value

ES.13 ECOLOGICAL SIGNIFICANCE OF IDENTIFIED RISKS

The ecological significance of the identified risks is often determined by evaluating whether estimated risk will make a difference or be observed in light of other factors that are influencing the environment, such as habitat alteration.

With the exception of species protected by law or regulation (threatened and endangered species) for which individual organisms are protected, EPA (1997a) guidance and policy state that ERAs should generally focus on the protection of local populations and communities of biota (e.g., the Study Area population of smallmouth bass, not the global population of smallmouth bass). Oregon's ERA guidance (ODEQ 1998) defines a local population for a stream or river as follows, "For aquatic species in moving water such as streams and rivers (lotic habitats), the local population comprises all individuals of the endpoint species within the stream segment within the contaminated area."

Contaminant concentrations, which, if not exceeded, are protective of local populations and communities were largely estimated in this BERA by extrapolating from effects on individual organisms or groups of organisms using an LOE approach. HQs ≥ 1 for a given LOE are considered to indicate potentially unacceptable risk to ecological receptors. For example, a HQ ≥ 1.0 might indicate the potential for reduced or impaired reproduction or recruitment of new individuals. HQs provide insight into the potential for adverse effects on organisms in the local population resulting from contaminant exposure. Any COPC with a HQ ≥ 1.0 in the final step of the risk characterization for at least one LOE in any location in the Study Area, or the risks of which could not be quantified in the BERA, was identified as a contaminant posing potentially unacceptable risk. Removal of contaminants with risks that could not be quantified from the list of contaminants posing potentially unacceptable risks resulted in the final list of contaminants forwarded for evaluation in the feasiblity study. The ecological significance of risk associated with each receptor-LOE-COPC combination posing potentially unacceptable risk was evaluated relative to the assessment endpoints to determine risk conclusions.

Ecological significance can be defined as the importance of an adverse effect on population, community, or ecosystem responses. Factors contributing to ecological significance considered in the BERA included the nature and magnitude of effects, the spatial and temporal extent of effects, uncertainties in the exposure assessment, uncertainties in the effects characterization, and concordance of the various LOEs used to assess risk to communities or populations. However, as there are no specific directions in EPA guidance (1997a) describing how to quantify ecological significance, the guidance calls for the use of professional judgment when describing the ecological significance of identified risks. The specific procedures used to evaluate ecological significance are presented in Section 3.4. Contaminants of ecological significance tended to meet the following criteria:

1. Had relatively high HQs in one or more environmental media
2. Had potentially unacceptable ecological risks over extensive areas
3. Spatial extent of potentially unacceptable risk encompassed many other contaminants that posed a risk at only one or a few locations in the Study Area
4. Had potentially unacceptable risks to multiple ecological receptors
5. Multiple LOEs indicated potentially unacceptable risks
6. Known or has potential to biomagnify in food webs

These criteria help risk assessors make professional judgments about whether the potential adverse effects on organisms in the Study Area from exposure to contaminants pose risk to local populations, and whether those risks are ecologically significant.

PCBs, PAHs, dioxins and furans, and total DDx[4] are the primary contaminants of ecological significance at Portland Harbor (Table ES-7). EPA identified 16 additional contaminants of ecological significance, as defined in Section 3.4.1, which are also listed in Table ES-7. Five of the sixteen (i.e., cyanide, ethylbenzene, perchlorate, manganese, and vanadium) are groundwater contaminants that only or primarily pose potentially unacceptable risks in transition zone water, which is sediment porewater containing a mixture of groundwater and surface water. The LWG will present its views regarding

[4] Depending on the LOE, different TRVs are used for PCBs, PAHs, dioxins and furans, and total DDx, so different names are used to describe these chemical groups at different places in the BERA. For example, total DDx includes two individual chemical forms each of DDT, DDD, and DDE.

EPA's list of 16 additional contaminants of ecological significance in a separate technical memorandum as part of its risk management recommendations.

Table ES-7. Chemicals Identified as Most Likely to be Contaminants of Ecological Significance

Contaminants of Primary Ecological Significance	
PCBs	Dioxins and furans
PAHs	DDT and its metabolites
Additional Contaminants of Ecological Significance	
Total chlordanes	Mercury
Lead	Cadmium
Copper	BEHP
Zinc	Dieldrin
Lindane (γ-HCH)	Cyanide
Tributyltin	Ethylbenzene
Perchlorate	$C_{10} – C_{12}$ TPH
Manganese	Vanadium

Contaminants posing potentially unacceptable risk listed in Table ES-5 but not in Table ES-7 fall within low ecological significance levels. All contaminants posing potentially unacceptable risk at the end of the BERA were recommended to be carried forward to the FS. Those classified as contaminants of ecological significance in Table ES-7 are recommended for consideration in developing and evaluating remedial action alternatives in the FS based on the pathways and factors considered in the BERA. Contaminants posing potentially unacceptable risk at the end of the BERA that are not listed in Table ES-7 are recommended for comparison with projected post-remedial action conditions to confirm that alternatives developed for the ecologically significant contaminants would also be protective of risks of low ecological significance.

ES.14 ECOLOGICAL RISK ASSESSMENT UNCERTAINTIES

By design, risk assessments are conservative in the face of uncertainty. In this context, conservative means efforts were made to minimize the chances of under-estimating exposure, effects, or risk. The uncertainty analysis portions of this BERA are intended to illustrate the degree of confidence in the BERA conclusions. An uncertainty analysis can help the risk manager focus on those aspects of ecological risk that can be reduced during site remediation with the greatest certainty that the selected remedy will result in benefit to and the protection of the environment.

Uncertainty in a BERA has four components: variation (e.g., a fish is exposed to a range of contaminant concentrations in water, not to a constant concentration of a contaminant); model uncertainty (e.g., use of a single species or several target ecological receptors within a feeding guild to represent all species within that guild introduces uncertainty because of the considerable amount of interspecies variability in sensitivity to a contaminant); decision rule uncertainty (e.g., use of standard EPA default values, such as assuming contaminant s are 100% bioavailable, because such defaults are used as single-point values throughout the BERA, despite having both variation and model uncertainty associated with them); and true unknowns (e.g., the effects of titanium in water on smallmouth bass survival, growth, and reproduction has never been studied and is unknown).

Consistent with the methods of the problem formulation (EPA 2008j), receptor-COPC pairs posing potentially unacceptable risk were identified using conservative methods and assumptions. Examples of conservatism include assumptions that environmental contaminant concentrations are 100% bioavailable and assumptions that resulted in low baseline TRVs, which, in the case of nutritionally essential metals such as copper, had to be adjusted upward because they were below nutritional requirements for some, but not all, fish species.

Not all uncertainties create a conservative bias. Some can lead to an under-estimation of risk (e.g., unavailability of exposure or effects data, thresholds that do not account for untested sensitive species, uncertainty about whether multiple COPCs present at the site interact synergistically, and uncertainty about whether metabolic processes increase the toxicity of accumulated contaminants in ways that are not observed in toxicity tests).

ES.15 PRIMARY CONCLUSIONS OF THE BERA

Combining the findings of the BERA as summarized in Tables ES-4, ES-5, ES-6, and ES-7 and as described in more detail in the BERA and its attachments, including the evaluations of ecological significance and uncertainty, the following primary conclusions can be made.

- In total, 93 contaminants (as individual contaminants, sums, or totals)[5] with HQ ≥ 1.0 pose potentially unacceptable ecological risk.
  - Differences in the specific TRVs used in different LOEs for total PCBs (e.g., total PCBs vs. specific Aroclor mixtures), total DDx, and total PAHs (17 individually measured contaminants such as naphthalene, as well as several groupings by molecular weight), all of which describe individual contaminants or a group of multiple but related individual chemical compounds, can result in different counts of the number of contaminants posing potentially unacceptable risk. The list of contaminants posing potentially unacceptable risks can be

[5] The five chemicals or chemical groups with concentrations that exceeded only the sediment probable effects concentration (PEC) and/or probable effects level (PEL) (i.e., chemicals that were not identified as COPCs for other benthic invertebrate LOEs: Aroclor 1254, chlordane [cis and trans], gamma- hexachlorocyclohexane [HCH] [Lindane], heptachlor epoxide, and total chlordane), ammonia and sulfide (which are conventional parameters), and residual-range hydrocarbons that had concentrations that exceeded only the total petroleum hydrocarbons [TPH] SQGs) are not included in this count.

condensed if all PCB, DDx and PAH compounds or groups are condensed into three comprehensive groups: total PCBs, total DDx, and total PAHs. Doing so reduces the number of contaminants with HQ ≥ 1.0 posing potentially unacceptable risks to 66.

- Risks to benthic invertebrates are clustered in 17 benthic AOCs.
- Sediment and TZW samples with the highest HQs for many contaminants also tend to be clustered in areas with the greatest benthic invertebrate toxicity.
- The COPCs in sediment that are most commonly spatially associated with locations of potentially unacceptable risk to the benthic community or populations are PAHs and DDx compounds.
- Not all COPCs posing potentially unacceptable risk have equal ecological significance.The most ecologically significant COPCs are PCBs, PAHs, dioxins and furans, and DDT and its metabolites.
- The list of ecologically significant COPCs is not intended to suggest that other contaminants in the Study Area do not also present potentially unacceptable risk.
- The contaminants identified as posing potentially unacceptable risk in the largest numbers of LOEs are (in decreasing frequency of occurrence) total PCBs, copper, total DDx, lead, tributyltin (TBT), zinc, total toxic equivalent (TEQ), PCB TEQ, benzo(a)pyrene, cadmium, 4,4′-DDT, dioxin/furan TEQ, bis(2-ethylhexyl) phthalate (BEHP), naphthalene, and benzo(a)anthracene. The remaining 78 contaminants posing potentially unacceptable risk were identified as posing potentially unacceptable risk by three or fewer LOEs.
- Of the three groups of contaminants (i.e., total PAHs, total PCBs, total DDx) with the greatest areal extent of HQs ≥ 1.0 in the Study Area, PAH and DDx risks are largely limited to benthic invertebrates and other sediment-associated receptors. PCBs tend to pose their largest ecological risks to mammals and birds.
- The combined toxicity of dioxins/furans and dioxin-like PCBs, expressed as total TEQ, poses the potential risk of reduced reproductive success in mink, river otter, spotted sandpiper, bald eagle, and osprey. The PCB TEQ fraction of the total TEQ is responsible for the majority of total TEQ exposure, but the total dioxin/furan TEQ fraction also exceeds its TRV in some locations of the Study Area.

ES.16 RISK MANAGEMENT RECOMMENDATIONS

Under EPA guidance (EPA 1998), risk management (Step 8 of EPA's 8-step ERA process) is a distinctly different process from risk assessment. Risk management decisions at Superfund sites are made by EPA risk managers. These risk managers are the EPA remedial project managers for the site. Risk management decisions are not made by the risk assessors who prepared the BERA, but risk managers normally ask risk assessors for their recommendations, advice, and professional judgment before making their risk management decisions. EPA asked the LWG to have their ecological risk assessors gather and provide any risk management recommendations they might have in a stand-alone document. The LWG's risk management recommendations will identify the contaminants, receptors, and AOCs that the LWG considers necessary and sufficient to develop and evaluate remedial alternatives that are protective of ecological resources. The FS will also evaluate whether remedial alternatives for these contaminants, receptors, and AOCs address the full list of contaminants posing potentially unacceptable risk.